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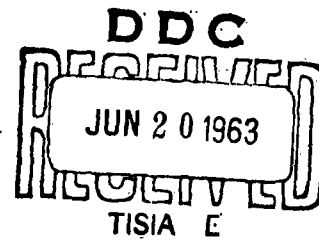# UNCLASSIFIED

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AN ATTEMPT AT MODELLING THE PROCESSES OF

SELF-REPRODUCTION AND EVOLUTION

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FOREWORD

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eight types, distributed equally. Random collisions of elements in the model are replaced by a random triggering device which actuates special commutators consisting of a self-blocking relay with a control output t_1 and two short-circuit contacts. The commutators join the element contacts in all possible ways, thereby allowing for various random "collisions" between them. The elements of all types A, B ...Z are evenly distributed in a plane and the contacts I, II, III, and IV of each element are linked by commutators with contacts I, II, III, IV of those eighty elements for which the element taken is the center. Thus, the total number of commutators in the entire model is $5.12 \cdot 10^6$. The commutator contacts t_1 are linked to the random triggering device which simultaneously actuates 10^5 commutators in random order.

Self-reproduction. In the initial state, all of the commutators are open. The random triggering device closes them for a short time, but then they are opened again. There can be no prolonged linkage between any elements, i.e., prolonged closing of the appropriate commutator. But if we arbitrarily form a chain of elements by closing the commutators linking contacts III and IV of the elements (the only limitation being the following: element A is always the first in the chain and element Z always the last), the resulting chain is in the first place stable, and secondly, it will begin to "reproduce" with a period of about 4-10 minutes, filling up the entire "medium" in about 2-4 hours. The reproduction process yields precise copies of the formed chain, and only in rare cases do structural changes ("mutations") occur. The altered structures reproduce just as the initial ones do.

Evolution. To observe the evolutionary process, the model is given an added possibility for variation, for which purpose the contacts t_2 of the elements are linked to a second random triggering device which likewise operates with a period of 1 second and emits five simultaneous random pulses. In addition, the element designs incorporate a predominance of chains taken from the series:

$$A - B - C - D - E - F - \begin{matrix} -X - B - C - D - E \\ \text{or} \\ - B - C - D \end{matrix} \qquad (1)$$

so that the chain A - B - Z will have an advantage over all the other chains, in which the element B does not follow element A. Thus, for example, over the chain A - D - C - B ... Z. The chain A - B - C - Z will likewise have an advantage over A - B - Z, etc. The chain A - B - C - D - E - F - X - B - C - D - E - Z is the most-highly organized in this sense. The ad-

vantage of the indicated chains consists in the fact that their stability (i.e., the period they can exist without reproduction) increases with increasing complexity. With such conditions, it is not necessary to introduce random chains following the triggering of the entire device. The simplest chains can themselves arise arbitrarily. Thus, the simplest chain A - Z arises in an empty medium after about 160 days; but once having formed, it reproduces rapidly and will fill up the medium in about 2 hours. The elements A, B...Z is such that reproduction is a necessary condition for the existence of any chain, so that when the entire medium is filled and the reproduction rate is slowed down due to the lack of free elements, some of the chains begin to break up into elements which return to the initial state. Thus, there will arrive a state of equilibrium, in which every chain will produce a daughter chain and break up into elements over an average period of 20 minutes. This will be accompanied by various "mutations". A positive mutation, i.e., the appearance of an A - B - Z chain will produce more daughter chains in its lifetime than will the A - Z chain. A new state of equilibrium will arise in about a day. Upon the filling of the medium with A - B - Z chains, we expect the "mutant" A - B - C - Z, etc.

The evolutionary process here considered branches out at some point, which may be seen as a consequence of (1). Thus, for example, the chains A - B - C - D - E - F - X - B - Z and A - B - C - D - E - F - B - C - Z are of equal value and can coexist in the medium, although the state of equilibrium between them is unstable, so that it is possible to lose one of the brances. For this reason, the final result of the "evolution" can either be the chain a) A - B - C - D - E - F - X - B - C - D - E, or the chain b) A - B - C - D - E - F - B - C - D - Z, despite the fact that the first chain has an absolute advantage over the second. However, the greater the total number of elements (n) taking part in the operation of the model, the less will be the probability of the evolutionary process coming up against a dead end. The total length of the process is estimated to be approximately 20 days.

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From the cybernetic standpoint, all machines with some degree of reproduction can be classed as follows:
    1. Neumann self-reproducing machines (Neumann, 1951).
    2. Penrose self-reproducing models and relay models.
    3. Automatic machines which use stamping, copying, printing, and reprinting.

Machines of the second type are characterized by the presence of a "random collision medium". In addition, all details of the self-reproduction process in these machines occur according to signals arising originally in the random triggering device or in the mechanical vibrator, i.e., outside the self-reproducing structures themselves. For this reason such machines can be called self-reproducing machines of the passive type, in which all details of the self-reproducing process occur according to signals oringinating in the program of the "parent" machine, i.e., within the self-reproducing structures themselves. For this reason, the Neumann machine can be called a self-reproducing machine of the active type. In passive machines, there is no reproduction of the random triggering device itself; in addition, all of their elements are assumed to be given. In automatic machines there is no reproduction of the control device which determines the copying, printing, etc. The significance of passive self-reproducing machines is due to their analogy with the real case of the self-reproduction of elementary cell structures in a medium of thermal motion, diffusion, and continuous random macromolecular collisions.

In self-reproducing machines of the passive type, the random collision process plays a fundamental role. For this reason they can be regarded as stochastic machines. We use this term in the same sense as Dr. Ashby [see note], who applies it to his homeostat. There is a deep similarity between random-search machines and the passive self-reproducing machines discussed above. The homeostat is called a self-organizing system because it performs something of an evolutionary process with selection based on a criterion, i.e., with selective destruction of unsuitable programs. On the other hand, reproduction and destruction are those factors which express the process of evolution of living systems. ([Note:] W. Ross Ashby, 1958, "The Uses of Cybernetics in Biology and Sociology," Voprosy Filosofii (Problems of Philosophy), 12, 110-117.)

What then is the issue of the analogy provided by self-reproducing machines in the consideration of the simplest living objects from the "black box" standpoint? At the present time it has not yet been established whether randomicity in nature is something fundamentally new or whether it is a manifestation of specific deterministic laws. It has likewise not been established that all groups of random phenomena in nature are of the same type. If we temporarily exclude from consideration the phenomena of life and confine ourselves to non-living nature under certain given, physical, chemical, and other conditions, it is possible to say that certain things (structures, forms) are encountered often, and others, quite on the contrary, -- rarely. Rarely encountered phenomena are considered impro-

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bable. The frequency with which things of low probability are manifested in nature is closely bound up with the probability of their random occurrence and speed of disappearance. All low-probability occurrences can be arranged in a ladder of decreasing probability. We can imagine structures for example which can manifest themselves on the earth's surface only once in several billion years. Moreover, (if we abstract ourselves from the property of reproduction) living objects can be placed at the very top of low-probability structures. In the absence of reproduction, the probabilities of the spontaneous appearance of even single-celled organisms are so low, that not a single such event might even occur throughout the history of the earth. It is interesting to note that in the above model of the evolutionary process, disregarding the property of self-reproduction, the time in which we can expect the random appearance of the $A - B - C - D - E - F - X - B - C - D - E - Z$ chain in the empty medium is about $3 \cdot 10^{59}$ billion years.

Thus, we can conclude that the property of self-reproduction of a low-probability structure appended to the universal premise that in nature everything flows and changes (and therefore has lower probability for destruction), yields in sum not destruction, but a harmonious process of the independent manifestation of low-probability states.

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